Spin-Lattice Interactions Mediated by Magnetic Field

Musfeldt, J.L., Cao, J., Vergara, L.I. (Tennessee); Litvinchuk, S.P. (Houston); Wang, Y.J. (NHMFL); Park, S., Cheong, S.-W. (Rutgers)

Introduction

The interplay between spin, lattice, charge, and orbital degrees of freedom drives rich physics in complex oxides. A high magnetic field offers an incisive opportunity to tune this balance. Here, we probe the local structure of $DyMn_2O_5$ using a combination of vibrational spectroscopy, lattice dynamical calculations, and magneto-infrared measurements. The latter was carried out at the NHMFL.

Results and Discussion

We focused our search for sizable magnetoelastic coupling on geometrically frustrated $DyMn_2O_5$.This system displays a rich magnetic field-temperature phase diagram, with a cascade of magnetic transitions and a series of magnetic phases, the critical fields for which depend on the direction of the applied field. Spin-lattice coupling in this multiferroic material is unusually strong as evidenced by mode sensitivity to the cascade of magnetic transitions, the large coupling constants, and the field dependence of numerous phonons (Fig. 1). We analyze these results in terms of field-induced local lattice distortions of the quasi-octahedral and pyramidal building blocks and discuss the consequences for ferroelectric polarization and the magneto-dielectric effect. That spin-lattice interactions can be mediated by an applied magnetic field has important consequences for the design of functional oxides, where many exotic properties derive from a flexible lattice and strong spin-lattice-charge mixing rather than a rigid lattice and separation of the different degrees of freedom.

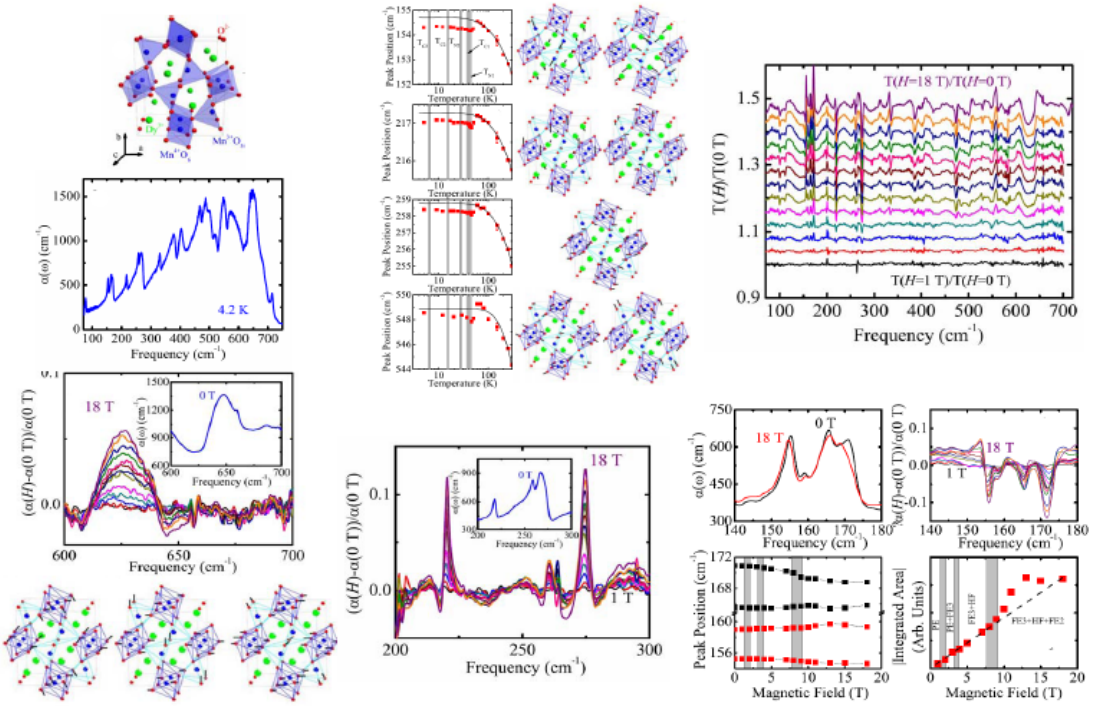

Figure 1: Crystal structure, infrared vibrational spectrum, calculated mode displacements, and sensitivity of particular phonons to temperature and applied magnetic field. Features between 280 and 760 cm^{-1} are Mn-O stretching and bending related. The lower energy features, calculated to be between 95 and 245 cm^{-1}, are mainly due to the relative motion of Mn-containing polyhedra and Dy^{3+} ions.

Acknowledgements

We thank the U.S. Department of Energy for support of this work.